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# Colour and Composition of Improved Pepino Cultivars at Three Ripening Stages

## Farbe und Zusammensetzung von verbesserten Pepinosorten in drei Reifestadien

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## Summary

Depending on its ripening stage, the pepino (*Solanum muricatum* Aiton) can be consumed as a vegetable for cooking (green), for salads (turning), or as a dessert fruit (ripe). We studied physical (weight and colour), physicochemical (moisture content, soluble solids content, pH, and titratable acidity), and chemical (ascorbic acid content, soluble and total proteins) characteristics of two improved pepino cultivars ('Sweet Round' and 'Sweet Long') at the three maturity stages associated to the three different uses. Colour parameter a* and the hue angle allowed an unambiguous distinction between the different ripening stages, while parameters L*, b* and chroma did not. Moisture content was high at all ripening stages, usually above 90%. As the ripening progressed, pH and ascorbic acid content raised. The soluble solids content increased from the green to the turning stage in both cultivars, but there was no variation between the turning and ripe stages in 'Sweet Round' and a decrease in the ripe stage in 'Sweet Long'. Titratable acidity, and as a consequence the maturity index, showed irregular behaviour with the highest values at the turning stage. Protein content was low and showed little variation among clones and ripening stages.

## Zusammenfassung

Pepino (*Solanum muricatum* Aiton) kann als Gemüse für die Küche (grüne Farbe), als Salatzugabe (Farbkomponente) oder als Dessert (reif) verzehrt werden. Es wurden physikalische (Gewicht, Farbe), physikalisch-chemische (Feuchtigkeitsgehalt, Gehalt an löslichen Feststoffen pH und titrierbare Säure) sowie chemische Eigenschaften (Ascorbinsäuregehalt, lösliche Proteine und Gesamtproteingehalt) von zwei verbesserten Pepino-Sorten ('Sweet Round' und 'Sweet Long') in drei Reifestadien für die verschiedenen Nutzungen untersucht. Der Farbparameter a* und der Farbton erlaubten eine eindeutige Unterscheidung zwischen den verschiedenen Reifezuständen, während dies für die Parameter L*, b* und die Farbintensität nicht zutraf. Der Feuchtigkeitsgehalt lag bei allen Reifezuständen i.a. über 90%. Während des Reifeprozesses stiegen pH und Ascorbinsäuregehalt an. Der Gehalt an löslichen Feststoffen nahm bei beiden Sorten bis zur beginnende Reife zu, aber es gab bei 'Sweet Round' keine Variation zwischen beginnender und Vollreife, bei 'Sweet Long' nahm er bei Vollreife ab. Titrierbare Säure, und in ihrer Folge der Reife-Index, zeigten mit dem höchsten Wert während zunehmender Reife ein irrreguläres Verhalten. Der Proteingehalt war gering und zeigte wenig Änderung zwischen Klonen und Reifestadien.

## Introduction

The pepino (*Solanum muricatum* Aiton) is a horticultural crop from the subtropical and temperate Andes grown for its edible fruits. Although it has been a neglected crop for a long time (NATIONAL RESEARCH COUNCIL 1989), there is an increasing interest for this fruit from European, Japanese, and the United States markets.

The pepino is a very versatile fruit and can be consumed in different ways depending on its maturity stage. When ripe, it has a flavour resembling the cantaloupe melon (SWEET 1986, RUIZ et al. 1992). At this stage it is consumed as a refreshing dessert fruit, or as an ingredient of fruit salads. It can also be used in meat, fish or seafood dishes (NATIONAL RESEARCH COUNCIL 1989), for preparing juices, preserves, icecreams and jams (MORLEY-BUNKER 1983). When the fruit is not fully ripe (turning stage) it has a cucumberlike scent and flavour and can be used in the same way. In fact, the English name for this species, pepino, has been directly taken from the Spanish word for cucumber (PROHENS et al. 1996a). When it is in an earlier ripening stage (green) it can be used as a vegetable in stews (ESQUIVEL and HAMMER 1991). An important point regarding each type of use is the precise identification of each stage. EL-ZEFTAWI et al. (1988) considered colour, firmness, juice content and °Brix levels as maturity indices for pepino fruit. However, in practice, only fruit colour is used as a maturity index criteria. HEYES et al. (1994) considered several visual scorings for determining the ripening stage of pepinos, but visual scoring is subjective and depends not only on the observer but also on the quality of light.

Other key factors for the success of the pepino as a "new" crop are its visual appeal, both of skin and flesh, its composition and nutritive value. However, to the present date, only a few limited studies on these subjects have been undertaken (REDGWELL and TURNER 1986, SHIOTA et al. 1988).

This work is aimed at finding objective colour characteristics that allow an objective distinction between the different maturity stages (ripe, turning and green) and to give information on the general composition characteristics of two new improved cultivars, 'Sweet Long' and 'Sweet Round' (RUIZ et al. 1997).

## Materials and methods

*Samples*

Pepino fruits from the varieties 'Sweet Long' and 'Sweet Round' were collected at three different maturity stages: green, turning and ripe. These stages correspond to the three possible uses of pepino: vegetable for cooking, for salads, and as a dessert fruit and are characterized by the following:
- Green: Completely green skin.
- Turning: Pale green skin with purple stripes becoming evident.
- Ripe: Yellow skin with purple stripes.

At each stage, 30 pepinos from each cultivar were picked from different positions on a spring-summer cycle plantation of pepinos (PROHENS et al. 1999b) in the Spanish Mediterranean, and were separated into two groups of 15 fruits (one for colour measurements and the other for composition analysis). The weight of individual fruits varied between 181 and 330 g, which are commercial sizes.

*Colour measurements*

For each fruit measured, the L*, a* and b* colour values were assessed with a HunterLab colour meter (Minolta CR300) fitted with a 8 mm diameter aperture.
- Skin colour: Two colour readings were taken in opposed positions on the surface of each fruit, taking care to avoid areas with purple stripes. From these values, the hue angle ($\tan^{-1}$ (b*/a*)) and the chroma $((a^*)^2+(b^*)^2)^{0.5}$ values were calculated.
- Flesh colour: The fruits were transversally cut and two readings at opposed positions were taken. The hue angle and the chroma were calculated.

*Chemical analysis*

Fruits from each cultivar and ripening stage were separated into three samples of five fruits. They were peeled and the small seeds contained in the central core were removed. Therefore, only the sliced pericarp was used for analysis. Characters considered were:
- Water content: This was determined by dessication in an oven at 105 °C until constant weight (AOAC 1993).
- Soluble solids content (SSC): This was measured at 20 °C with a digital refractometer and the results expressed as °Brix (AOAC 1993).
- pH: 5 g of edible pulp were blended with water in a Sorvall Omnimixer. The pH was measured at 20 °C with a pH-meter (Crison micropH 2000) (AOAC 1993).
- Titratable acidity (TA): After determination of the pH, the solution was titrated with 0.1 N NaOH using phenolftalein as indicator. The results were expressed as the percentage of anhidrous citric acid (AOAC 1993).
- Maturity index (MI): It was calculated as the ratio SSC:TA.
- Ascorbic acid content (AAC): 15 g of homogenate were added to 30 mL of 4.5% metaphosphoric acid with magnetic stirring for 15 min. The mixture was filtered under vacuum and the filtrate was diluted to 50 mL with distilled water. An aliquot of the acid extract was then filtered prior to injection of 20 mL into a chromatographic system. To quantify the total amount of ascorbic acid (DHAA + AA) present in the samples, 1 mL of filtrate was added to 0.2 mL of dithiothreitol solution (20 mg/mL) as a reduction agent and left to stand in darkness for two hours. After reduction, samples were filtered and injected into the chromatographic system.

  The external standard calibration method, considering the ascorbic acid peak area was used for calculations.
- Soluble proteins: Were determined on lyophilised samples of the sliced pericarp using a Bio-Rad kit for the Bradford reaction (BRADFORD 1976).
- Total proteins: Were determined by the Kjeldahl method (AOAC 1993).

*Correlation analysis*

Correlations between chemical characters were performed in order to determine if variations in one character results in changes in the others.

## Results

*Colour measurements*

- Skin colour: Values for L* were not particularly different between clones although they differed among the ripening stages, the turning stage having a higher L* value than the green and ripe stages (Table 1). For both clones a* values decreased consistently as ripening progressed, indicating a loss of the green colour. However, although for the green and turning stages there are no differences in these values among clones, for the ripe stage a* values are much lower for 'Sweet Round' than for 'Sweet Long'. Regarding the b* value, it decreases slowly in the turning stage and shows a strong increase in the ripe stage indicating an increase in yellow tones. The hue angle decreases consistently with the maturity stage, reaching values near 90° (pure yellow) in the cultivar 'Sweet Long'. The chroma values, which refer to colour saturation, decrease in the turning stage, but increase again in the ripe stage, where they reach the maximum values. The highest saturation is obtained for the ripe stage in 'Sweet Long'.
- Flesh colour: Values for L* are lower than for skin in all the stages (Table 2). Differences found between stages are also lower than for the skin. As with the skin colour, a* values decrease with the maturity stage, indicating that the colour turns yellow. However, values for this parameter are much higher than those for the skin indicating that the flesh has less green colour than the skin. Furthermore, unlike the skin colour, there are no differences between cul-

Table 1. Values of the skin colour parameters for cultivars 'Sweet Round' and 'Sweet Long' at three different ripening stages[a]. *Parameter der Schalenfarbe von 'Sweet Round' und 'Sweet Long' in drei verschiedenen Reifestadien.*

| | 'Sweet Round' | | | 'Sweet Long' | | |
|---|---|---|---|---|---|---|
| | Green | Turning | Ripe | Green | Turning | Ripe |
| L* | 57.91±0.44 | 64.36±0.40 | 57.36±0.42 | 58.14±0.47 | 64.62±0.52 | 59.58±0.60 |
| a* | –11.82±0.16 | –8.60±0.25 | –7.84±0.17 | –11.49±0.22 | –8.14±0.31 | –3.28±0.24 |
| b* | 19.96±0.16 | 18.65±0.44 | 23.56±0.36 | 20.39±0.24 | 17.57±0.39 | 28.04±0.40 |
| hue angle | 120.58±0.22 | 114.79±0.56 | 108.48±0.30 | 119.32±0.32 | 114.69±0.60 | 96.66±0.47 |
| Chroma | 23.20±0.22 | 20.56±0.47 | 24.84±0.38 | 23.42±0.31 | 19.40±0.45 | 28.27±0.40 |

[a] All values are means of thirty replicates ± SE.

Table 2. Values of the flesh colour parameters for cultivars 'Sweet Round' and 'Sweet Long' at three different ripening stages[a]. *Parameter der Farbe des Fruchtfleisches von 'Sweet Round' und 'Sweet Long' in drei verschiedenen Reifestadien.*

| | 'Sweet Round' | | | 'Sweet Long' | | |
|---|---|---|---|---|---|---|
| | Green | Turning | Ripe | Green | Turning | Ripe |
| L* | 48.08±0.91 | 48.15±0.82 | 44.85±0.32 | 47.99±0.55 | 50.02±0.66 | 45.69±0.36 |
| a* | –6.60±0.12 | –5.02±0.24 | 0.30±0.09 | –6.90±0.10 | –5.73±0.13 | 0.29±0.30 |
| b* | 15.72±0.21 | 18.20±0.30 | 18.25±0.15 | 17.14±0.22 | 19.07±0.28 | 20.62±0.29 |
| hue angle | 113.66±0.29 | 106.30±0.50 | 89.64±0.40 | 112.90±0.24 | 107.80±0.32 | 89.70±0.94 |
| Chroma | 17.05±0.23 | 18.89±0.34 | 18.26±0.16 | 18.48±0.23 | 19.92±0.29 | 20.67±0.29 |

[a] All values are means of thirty replicates ± SE.

Table 3. Composition characteristics of 'Sweet Round' and 'Sweet Long' pepinos at three ripening stages[a]. *Merkmalskomponeneten von 'Sweet Round' und 'Sweet Long' in drei Reifestadien.*

| | 'Sweet Round' | | | 'Sweet Long' | | |
|---|---|---|---|---|---|---|
| | Green | Turning | Ripe | Green | Turning | Ripe |
| Moisture (%) | 90.91±0.10 | 90.74±0.99 | 91.05±0.89 | 90.70±0.16 | 89.25±0.39 | 91.53±0.14 |
| SSC (°Brix) | 6.40±0.09 | 7.32±0.02 | 7.33±0.34 | 6.53±0.09 | 8.65±0.48 | 7.97±0.18 |
| TA (mg/100 g) | 0.246±0.016 | 0.317±0.005 | 0.203±0.025 | 0.264±0.025 | 0.529±0.018 | 0.314±0.036 |
| pH | 4.74±0.16 | 5.08±0.14 | 5.40±0.17 | 4.89±0.03 | 4.78±0.11 | 5.19±0.03 |
| MI | 26.02±1.93 | 23.09±0.40 | 36.10±5.17 | 24.75±2.23 | 16.35±1.42 | 25.37±4.35 |
| AAC (mg/100 g) | 12.98±0.44 | 17.90±0.81 | 29.39±3.38 | 15.97±0.13 | 27.18±2.86 | 38.59±3.14 |
| Soluble proteins (g/100 g) | 0.112±0.006 | 0.067±0.007 | 0.072±0.003 | 0.110±0.007 | 0.071±0.004 | 0.072±0.014 |
| Total proteins (g/100 g) | 0.928±0.036 | 0.949±0.128 | 0.920±0.121 | 0.949±0.041 | 1.098±0.066 | 0.863±0.027 |

[a] All values are means of thirty replicates ± SE.

tivars for a* in the ripe stage. Values for parameter b* also show some differences with respect to the skin. In this case, the b* values increase from the green to the turning stage and show no variation ('Sweet Round') or an additional increase ('Sweet Long') when passing from the turning to the ripe stage. The hue angle of the skin decreases consistently with the ripening stage, with values lower than those for the hue angle and very near to 90° (yellow). Chroma values are generally lower than those for the skin, and do not vary particularly between clones nor between maturity stages.

## *Chemical analysis*

- Moisture content: It was high in all the stages and in both clones, showing very little variation (Table 3). All values were comprised between 89.2 and 91.6%.
- Soluble solids content: SSC was low in the green stage (around 6.5 °Brix) in both clones (Table 3). However, it increases considerably in the turning stage, especially for clone 'Sweet Long'. In 'Sweet Round' there are no changes from the turning to the ripe stage, yet in 'Sweet Long' there is a decrease, although the final values are higher than those for 'Sweet Round'.
- pH and titratable acidity: pH values are not particularly variable, although for both clones they increase with the maturity stage (Table 3). TA shows irregular behaviour with an important increase from the green to the turning stage, especially for clone 'Sweet Long'. In the turning to ripe stage there is a decrease at the ripe stage where values are low (< 0.35%).
- Maturity index: MI shows a decrease from the green to the turning stage and later an increase from the turning to the ripe stage. Values for MI are very high when compared to other fruits, mainly because of the low values for the TA.
- Ascorbic acid content: It increases steadily with the maturity stage (Table 3). At the same maturity stage, cultivar 'Sweet Long' has a higher AAC than 'Sweet Round'. Values in the ripe stage almost reach 40 mg/100 g in 'Sweet Long' and 30 mg/100 g in 'Sweet Round'.
- Soluble proteins: Values for the soluble protein content are low in both clones and the differences between clones are small (Table 3). However, protein

Table 4. Correlations between composition characters (n=9). Values for the upper diagonal correspond to 'Sweet Round' and lower diagonal to 'Sweet Long'a.
*Korrelation zwischen Setzungsmerkmalen – Werte von der Oberdiagonale entsprechen 'Sweet Round' und der Unterdiagonale 'Sweet Long'.*

| | SSC | TA | pH | MI | AAC |
|---|---|---|---|---|---|
| SSC | | –0.046 (0.907) | 0.606 (0.084) | 0.452 (0.222) | 0.299 (0.435) |
| TA | 0.641 (0.063) | | –0.410 (0.274) | –0.906 (0.001) | –0.382 (0.310) |
| pH | –0.131 (0.736) | –0.543 (0.131) | | 0.636 (0.066) | 0.598 (0.089) |
| MI | –0.490 (0.181) | –0.953 (<0.001) | 0.536 (0.137) | | 0.479 (0.192) |
| AAC | 0.629 (0.069) | 0.043 (0.912) | 0.520 (0.151) | 0.051 (0.897) | |

[a] Values between brackets indicate the signification level for the correlation.

content for the green stage is much higher (almost two-fold) than for the turning and ripe stages.
- Total proteins: Protein content of both clones is very similar, around 1 % on a wet basis, with no important differences among ripening stages.

### *Correlation analysis*

Table 4 shows the correlations among chemical characters that usually vary during ripening and that could be used as maturity indexes. We have found no significant correlations among the characters considered, except for a negative correlation between titratable acidity and maturity index. This indicates that the changes observed in the maturity index are mainly due to the changes in the titratable acidity.

## Discussion

HEYES et al. (1994) suggested that colour data obtained with a colourmeter do not allow distinction between the different ripening stages. However, we have found that it is possible, at least in the clones used by us, to make an unambiguous identification of the maturity stages using colourmetric data of the skin colour. The best parameters for distinguishing between different stages are the a* value and the hue angle. This can be very important in mechanically grading the fruits postharvest for their different maturity stage, and therefore for their type of use. It also avoids subjective grading, which depends on many factors.

In addition, values for the flesh colour are quite different between ripening stages. Values for the ripe fruit are yellow (hue angle approximately 90°) and this makes the fruit more appealing. At earlier stages the fruit has a greener colour which is more adequate for its use as a vegetable.

Values obtained for the moisture content confirm earlier findings obtained by other authors (REDGWELL and TURNER 1986). This means that the pepino is a fruit with a low caloric content, therefore supporting the refreshing and diuretic character of this fruit (NATIONAL RESEARCH COUNCIL 1989).

SSC increases from the green to the turning stage. REDGWELL and TURNER (1986), EL-ZEFTAWI et al. (1988) HEYES et al. (1994), and AHUMADA and CANTWELL (1996) recorded a similar behaviour for cultivars 'Golden Splendour', 'El Camino', and 'Toma', respectively. However, in most cases, these authors also found that the SSC increased further when passing to the ripe stage. In our case, we found no increase, and even a decrease, in the SSC from the turning to the ripe stage. This different behaviour may suggest differences between different clones in the ripening process. Another plausible and more likely explanation is that the high temperatures (>30 °C), which are usual during the ripening process in spring-summer plantations may have some negative effects on fruit ripening (PLUDA et al. 1993). Several studies have demonstrated that ripe fruits from the spring-summer cycle have a lower SSC than those from the autumn-winter cycle (RUIZ et al. 1997, PROHENS et al. 1999b). In fact, values obtained by us are relatively low in the case of the ripe stage.

Unlike pH, which shows few changes, TA shows abnormal behaviour. REDGWELL and TURNER (1986) found an increase with the ripening stage in cultivar 'El Camino', and AHUMADA and CANTWELL (1996) found no changes in the acidity values at different stages of ripeness of cultivar 'Toma'. The pepino shows an impressive variation among clones for fruit characters and this probably accounts for a considerable part of the differences found. Furthermore, environmental conditions may also affect the TA of the fruit (RUIZ et al., 1997). As with the SSC, TA is also affected negatively by high temperatures at the ripe stage (PROHENS et al. 1999b). Changes in TA also induce irregular behaviour of the MI, which discards its use for identifying the maturity stage. The high values found for MI as a consequence of low values in the TA for the ripe stage contribute to support the "subacid" character of this fruit (NATIONAL RESEARCH COUNCIL 1989).

Values obtained for the AAC are high, especially when ripe. The consumption of the pepino can contribute effectively to providing a considerable quantity of the ascorbic acid necessary in the diet. This is especially true for the ripe and turning stages, when the fruit is consumed raw. At the green stage during the boiling process, most of the ascorbic acid is degraded. In terms of the protein content, it only provides a small, non-significant, contribution to diet.

Although both clones, 'Sweet Long' and 'Sweet Round', were selected for being used mainly as a dessert fruit (RUIZ et al. 1997), the differences found between cultivars in composition for each ripening stage suggests that special cultivars could be selected for each type of use. In fact, several cultivars seem specially suitable for their use in salads, as they have a very crisp texture (NUEZ and RUIZ 1996). However, when they are ripe most of these clones have poor organoleptic qualities.

In conclusion, this work indicates that for these two new improved cultivars, 'Sweet Round' and 'Sweet Long', fruits for marketing can be classified by objective colour measurements into the three different stages associated to each consumption use. Composi-

tion data are different for most characters for each ripening stage. The irregular behaviour of some characters confirms the special features of the ripening process of this fruit and may be of great relevance for the horticultural management of this crop.

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